Medical System Concept of Operations for Mars Exploration Missions

HRP INVESTIGATOR'S WORKSHOP

1.23.17

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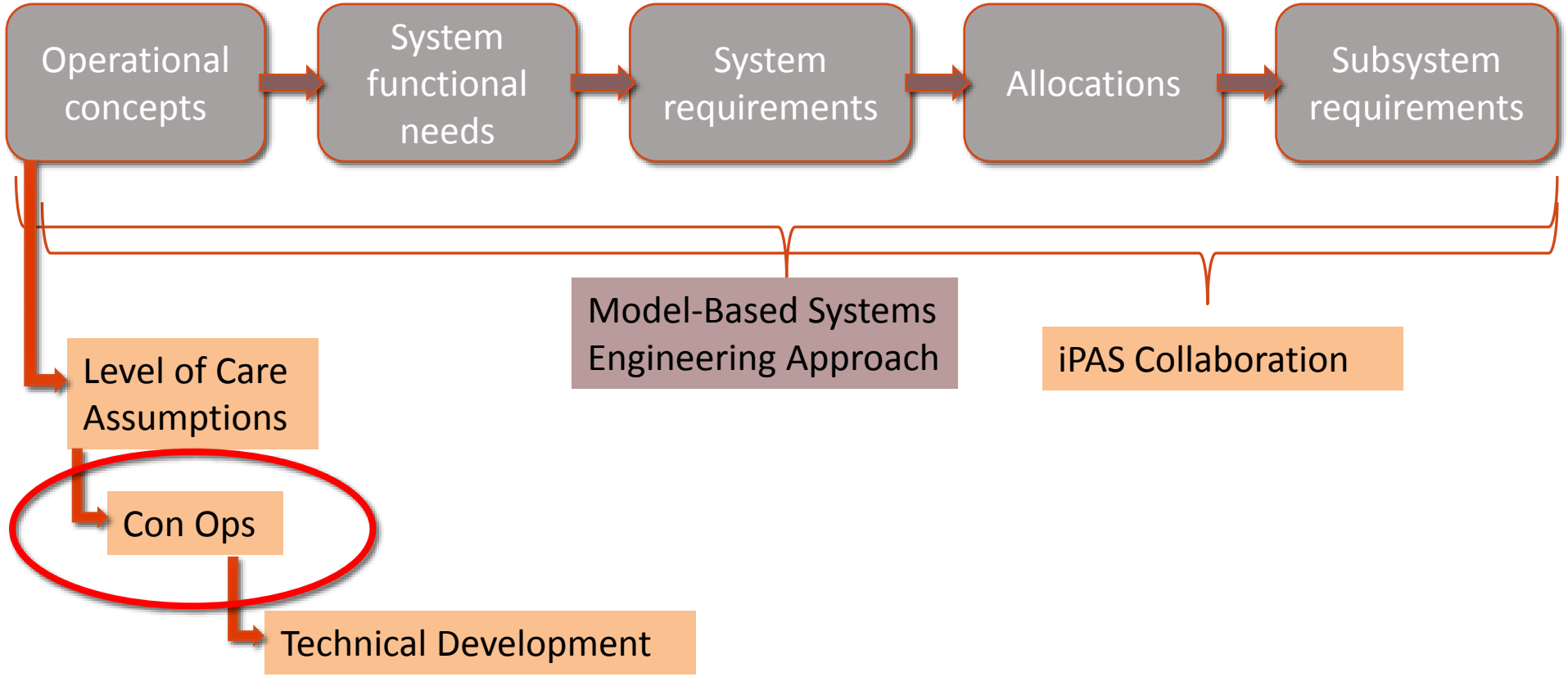
Systems Engineering Session Talks

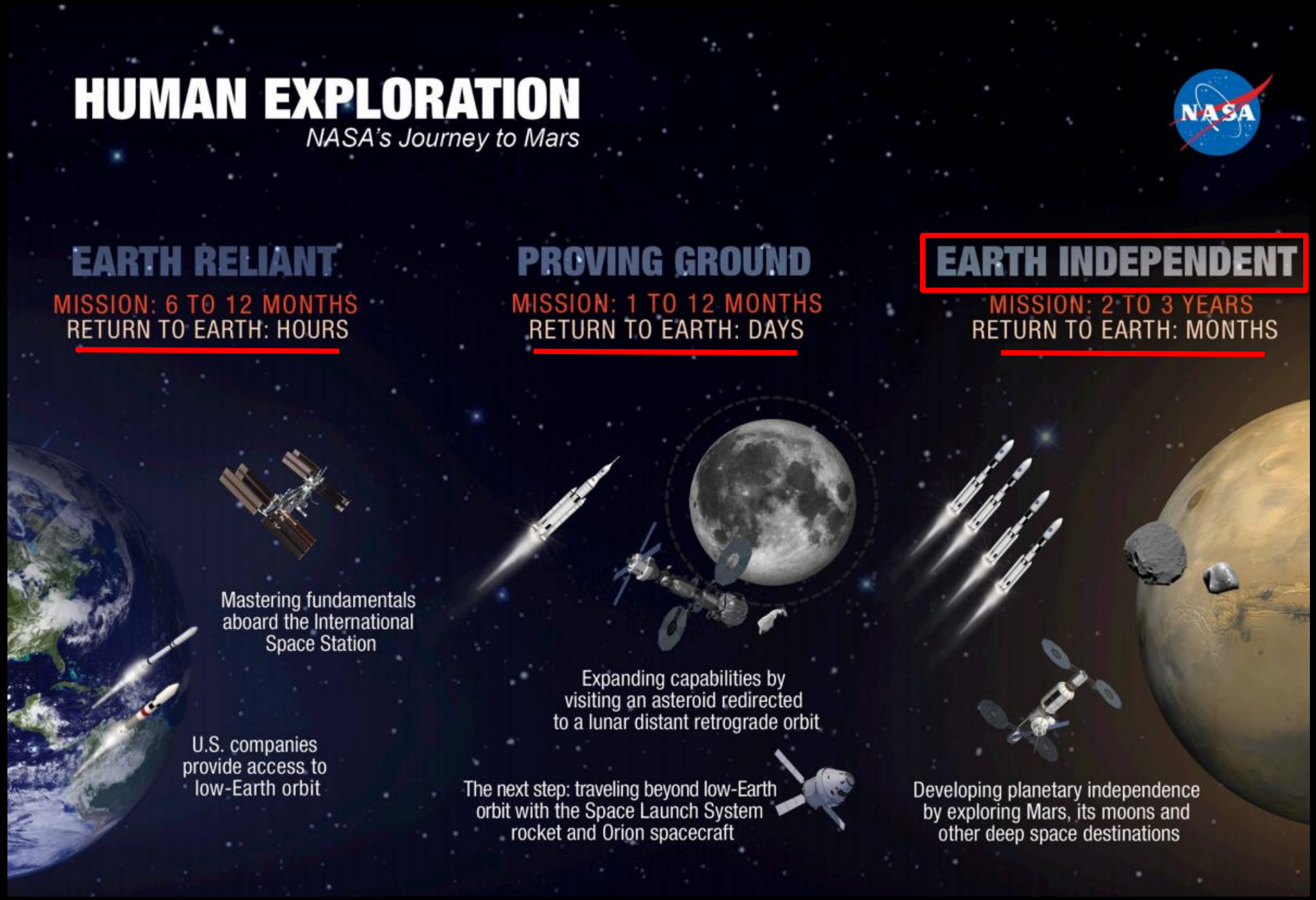


The needs identified by this work will drive future ExMC research

Overview

- Mars DRM
- Level of Care V
- Concept of Operations Development
- Scenario Tree
- Example Scenario
- Building on ConOps Content for System Development

Mars Design Reference Mission



https://www.nasa.gov/sites/default/files/files/NextSTEP-EMC-Reference.pdf

Design Reference Mission

Mars DRM Transit Phase

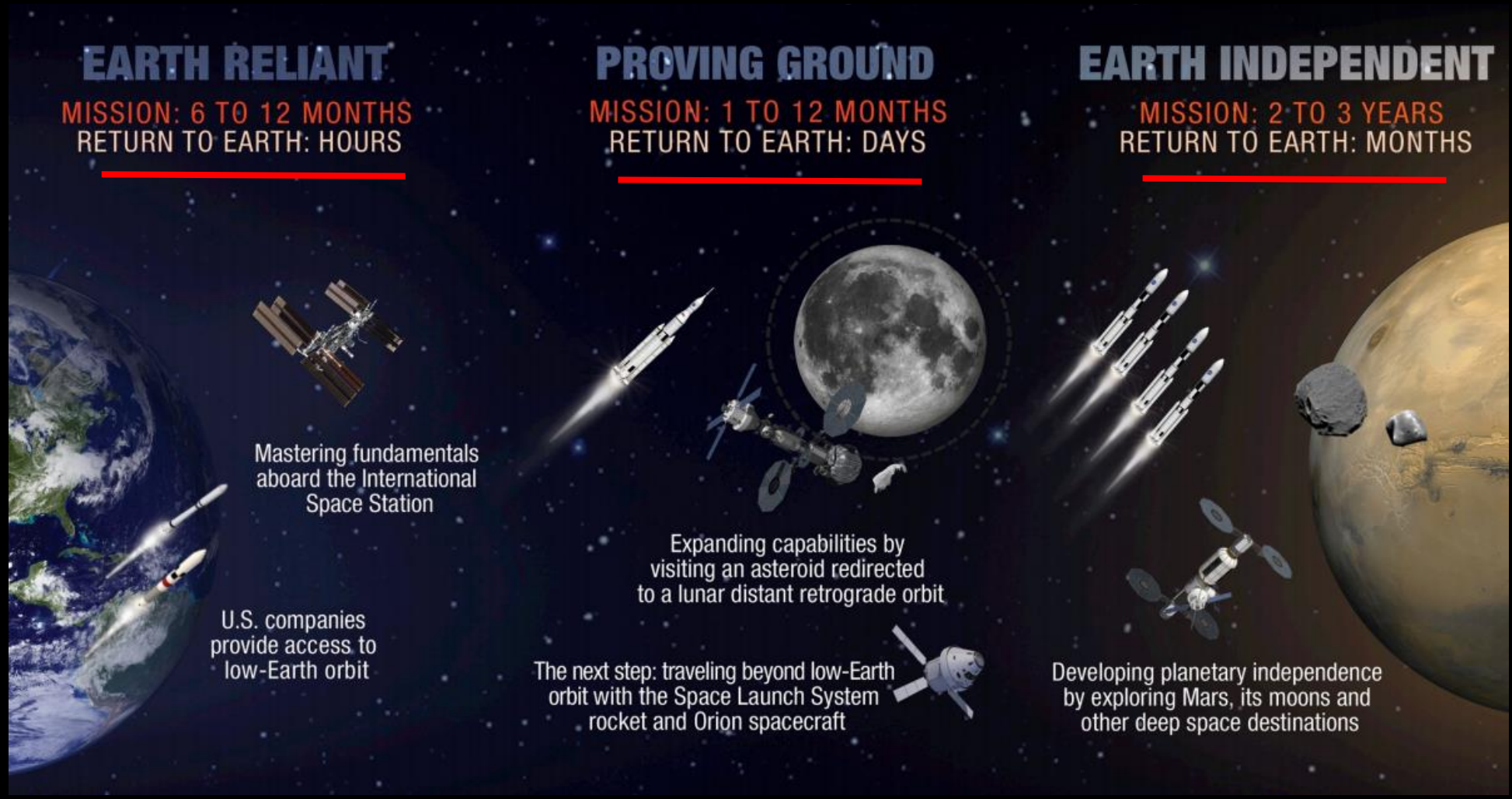
- Crew: 4
- Transit:
  - Phase 1 (Earth -> Mars): 210 days
  - Phase 2 (Mars -> Earth): 210 days
- Time to definitive medical care:
  - There is no evacuation capability
- Resupply: limited or none (pre-position may be an option)
- Comm delay: 22 mins each way
  - Limited real-time telemedical consultations for information and guidance = autonomy
- The first version of the ConOps will include transit ops only, no surface, EVA or launch/landing


Level of Care Definitions

Level I - III

Level III and IV

Level V



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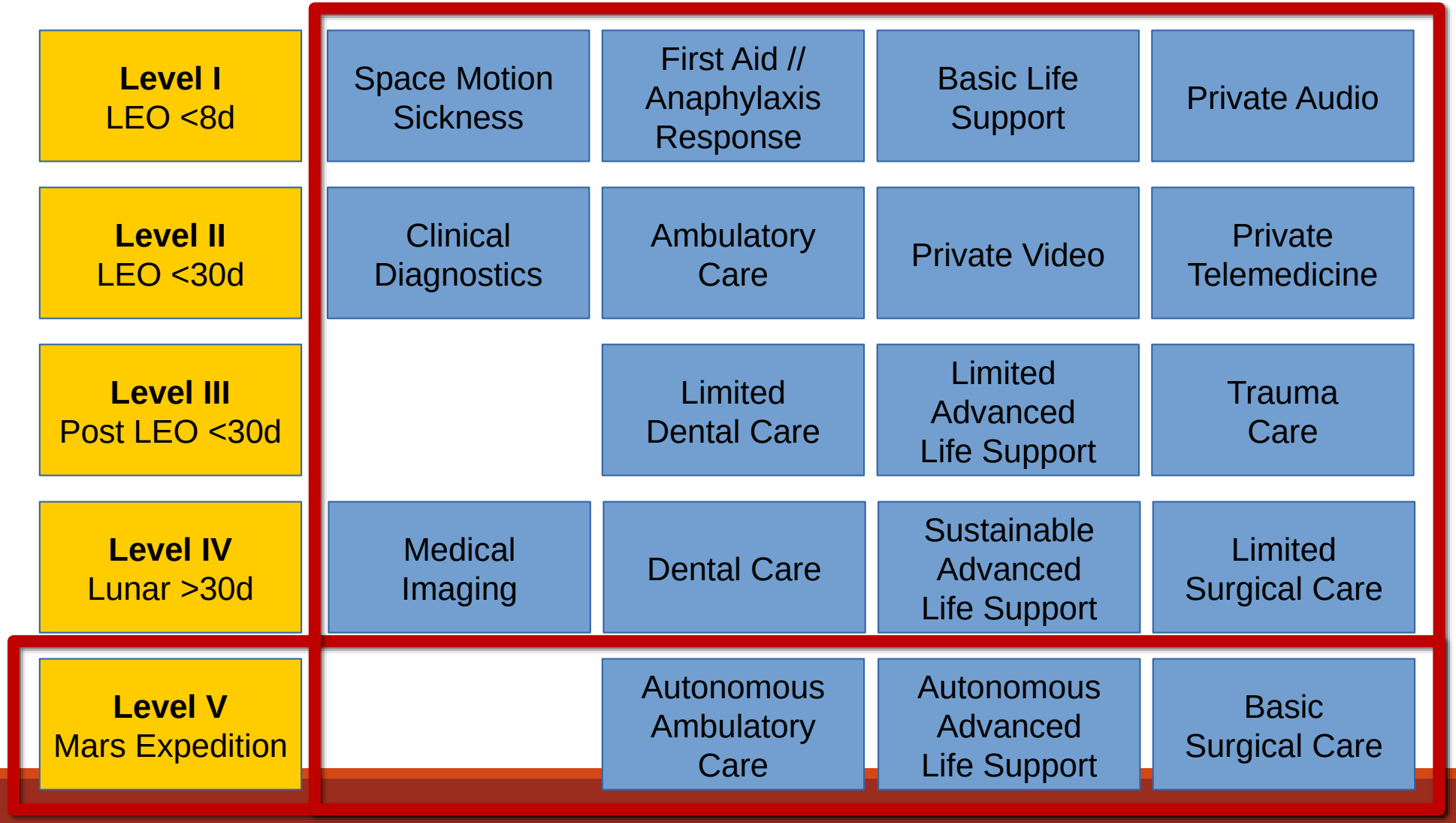
NASA-STD-3001 Levels of Care



STD-3001: Level of Care V

Exploration missions will face challenges not faced by prior programs. It will present significant new challenges to crew health that will be unique from those experienced during missions conducted in low earth orbit (LEO), including:

- extended transit and surface times
- effects of variable gravity environments

Because of this, there will be no:

- Limited real-time communication
- No regular resupply
- No evacuation to definitive care
- High level of risk

Therefore, medical care will be different:

- Preventive strategies critical
- **Autonomous** advanced care: Diagnosis, Treatment, Rehabilitation
- Physician Astronaut is self-sufficient and relies on ground support for consults

Medical System: Providing Value

Meet required levels of care

Adapt existing standards

Enhance medical capability

Maximize crew autonomy

Minimize crew burden

Integrate systems

Maximize flexibility

Maintain ground awareness

➔ **Maximize crew health and well-being to maintain performance and enable mission success!**

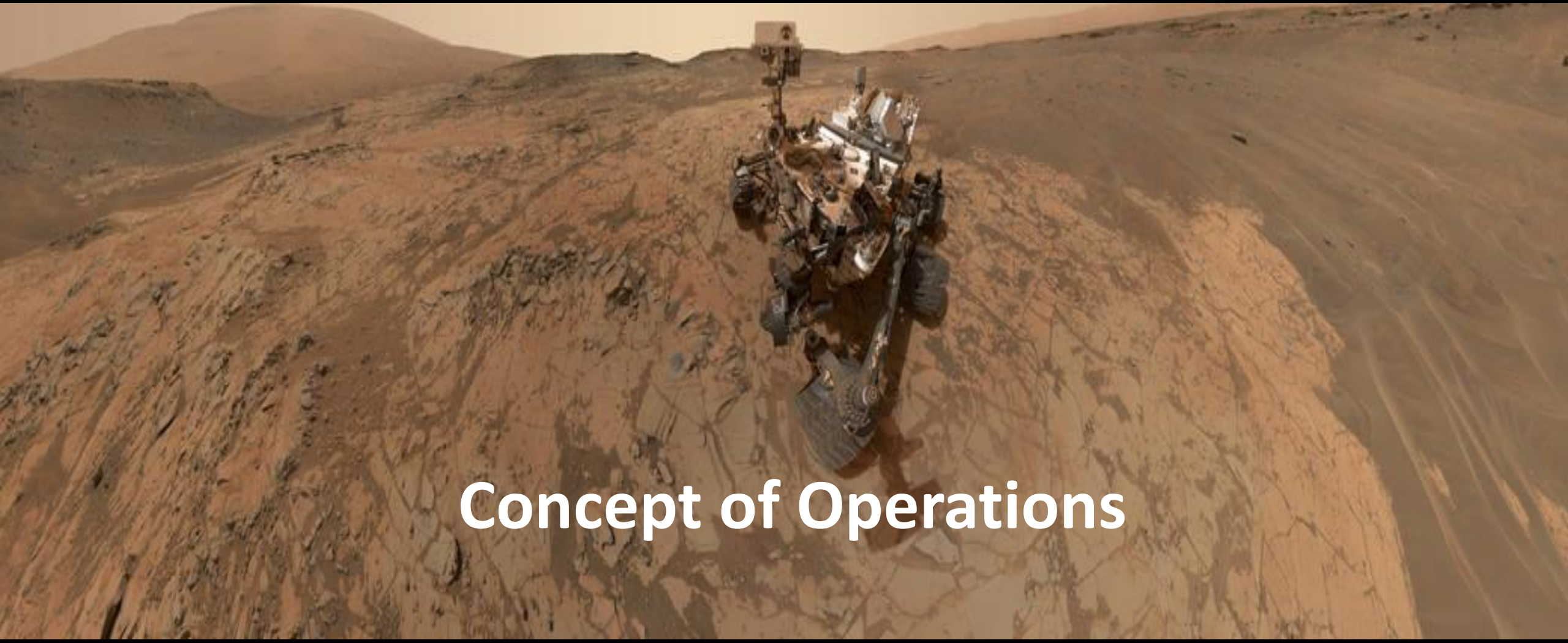
Enhancing Mission Success

What the medical system should be…

- A system that …
  - Decreases cognitive burden
  - Increases capability
  - Ensures autonomy
  - Maximizes flexibility
- Software and systems integration
- **Integration with vehicle systems will be promoted where possible.**

What the medical system should not be…

- Ground – MCC centric
- Difficult to use
- Difficult to maintain
- So expensive and “robust” that it never gets built



Concept of Operations

Building the Vision: Concept of Operations

- Definition
- Document Outline
- Scenario Tree
- Activity Flowchart
- Narratives & Assumptions
- Storyboard

ConOps Definition

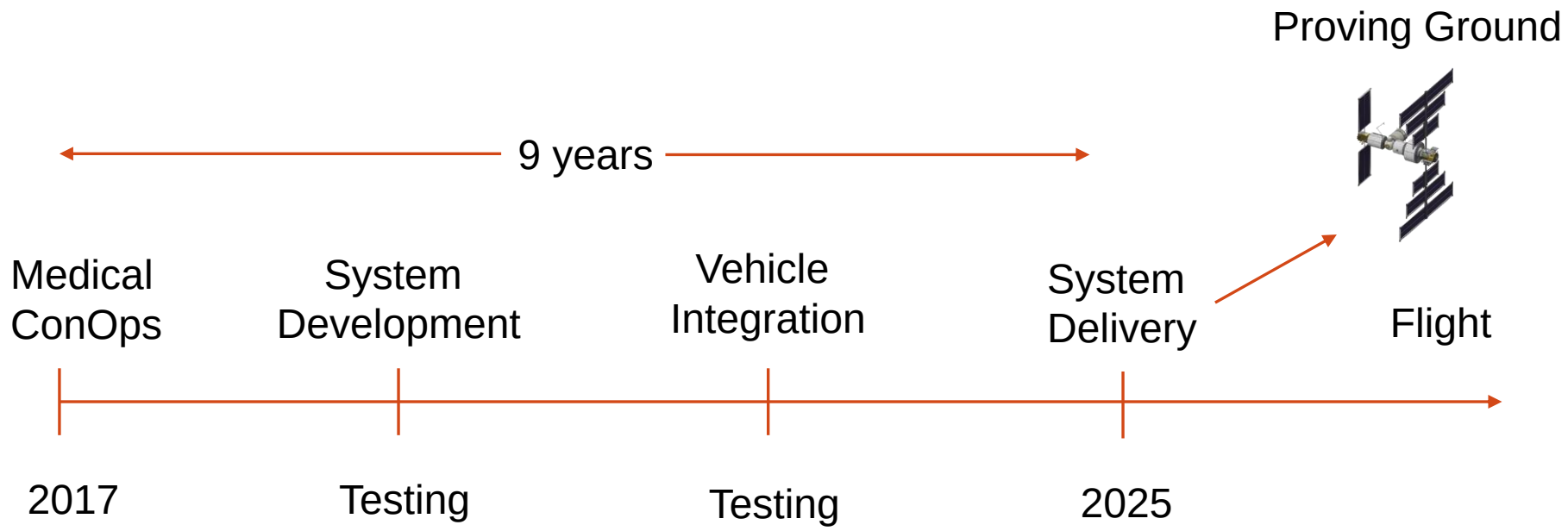
- From Appendix A of 7123.B NASA Systems Engineering Processes and Requirements:

http://nodis3.gsfc.nasa.gov/npg_img/N_PR_7123_001B_/N_PR_7123_001B__AppendixA.pdf

  - "Concept of Operations (ConOps): Developed early in Pre-Phase A, describes the overall high-level concept of how the system will be used to meet stakeholder expectations, usually in a time sequenced manner. It describes the system from an operational perspective and helps facilitate an understanding of the system goals. It stimulates the development of the requirements and architecture related to the user elements of the system. It serves as the basis for subsequent definition documents and provides the foundation for the long-range operational planning activities."

System needs for the transfer vehicle need to be identified.

Why now?


Proving Ground
9 years
Medical ConOps
System Development
Vehicle Integration
System Delivery
Flight
2017
Testing
Testing
2025

Document Outline

1. Introduction
2. Change Authority
3. Applicable and Reference Documents
4. Mars Mission Overview and Scenarios
    A. Mission Overview
    B. Mission Phases
        i. Integration and Testing
        ii. Launch
        iii. Cislunar Rendezvous
        iv. Mars Transit
            a. Overview
            b. IVA Scenarios
                - Prose
                - Activity Diagrams
                - Assumptions
            c. EVA Scenarios
        v. Mars Rendezvous
        vi. Mars Entry, Decent, & Landing (EDL)
        vii. Mars Surface Ops
        viii. Mars Ascent
        ix. Earth Transit
        x. Earth EDL & Recover

Purpose of Scenario Content

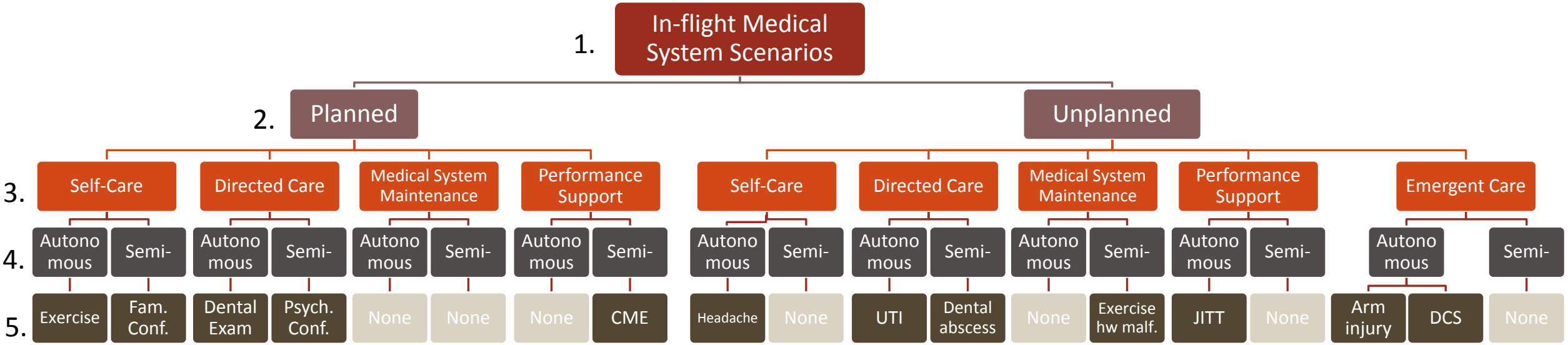
Narratives

- Contain *representative descriptions* of medical conditions and medical system implementation details to provide a vivid picture to the reader.
- Implementation options and decisions such as sensors, user interface details, etc. will be defined as part of the subsequent system development products.
- These are not necessarily the system design solutions!

Activity diagrams

- Contain more generic activity representations that will be *used as a basis for system requirements and architecture development*.

Scenario Tree



See backup slides for acronyms.

1. The current focus of the concept of operations is to portray the in-flight medical system envisioned for transit to Mars.
2. The scenarios have been categorized into planned and unplanned medical operations.
3. Nine medical scenario types have been identified to organize the range of crew interactions with the medical system.
4. The medical system will need to support a range of autonomy from the ground. Autonomous = no expectation or opportunity for ground input; Semi-autonomous = expectation or desire for ground input when available.
5. Twelve scenarios will be used to exemplify the interaction with the medical system, spanning the space of the system's functions.

Additional information:

- Vehicle systems will be used in all scenarios and may include communication systems and vehicle sensors.
- For each scenario, the crewmembers involved may include the patient, primary caregiver, secondary caregiver, or any crewmember.

Assumptions

Assumptions for All scenarios

1. Caregivers have varying medical skill sets and the Medical System will complement the Caregiver's skillset.
2. The Medical System has varying levels of support and the Caregiver can utilize the system as much or little as desired.
3. The timing of synchronization between the in-flight and ground medical data systems will depend on factors such as telemetry bandwidth, distance from earth, priority of data, etc.
4. Medical resources are part of the medical system.

Assumptions for Scenario Type: Unplanned, Self-Care, Autonomous from Ground

1. The caregiver is a physician.
2. The “resources” in this scenario are medication.

Storyline for this Scenario

Headache

Narrative

Scenario Type: Unplanned, Self-Care, Autonomous from Ground

PT = Patient GS = Ground System MS = Medical System

Recognize Symptoms

For the past few hours the PT has been experiencing a headache strong enough to impede his work.

Define Treatment Plan

The PT recognizes this headache as typical of those he has had in the past. He decides that there is no need to involve the CG and will treat with acetaminophen, as he had the other headaches. The PT accesses his personal health record within the MS and logs his current problem and his desire for acetaminophen. The MS quickly cross-checks the medical inventory system and determines that the acetaminophen supply is adequate and verifies that it is not contra-indicated for this PT.

Perform Treatment Plan

The MS dispenses the proper acetaminophen dose to PT, who grabs the pills and washes them down with some water from his drink bag. The MS updates the PT's health record with this new event and logs the medication administered. The MS updates the VS inventory tracking system.

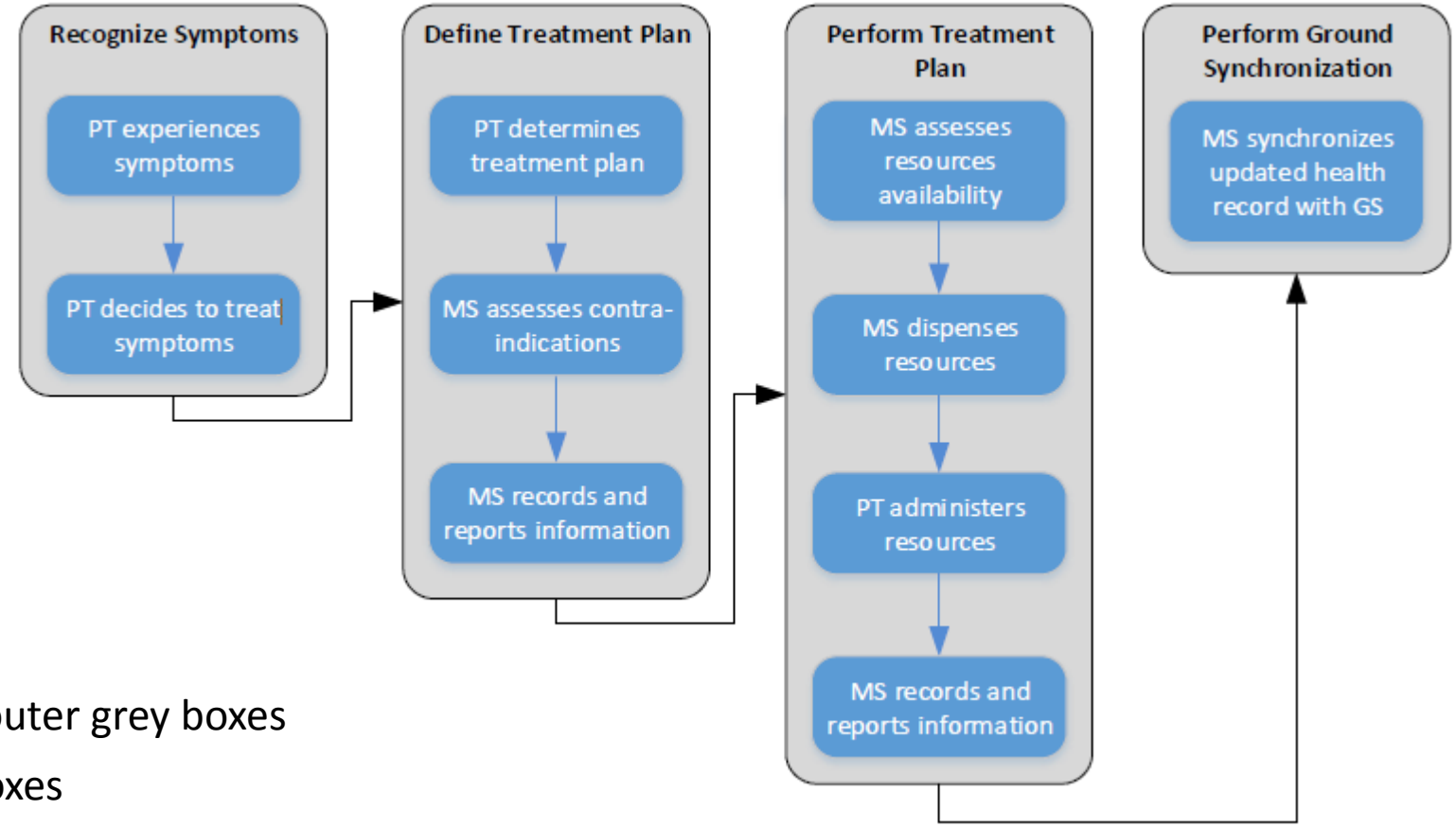
Perform Ground Synchronization

The MS coordinates with the VS to downlink the CM's updated health record and synchronize the onboard and ground electronic health systems.

Activity Flowchart

Scenario Type: Unplanned, Self-Care, Autonomous from Ground

PT = Patient GS = Ground System MS = Medical System



Identifiers:

- Activity Groups: outer grey boxes
- Activities: blue boxes

Summary

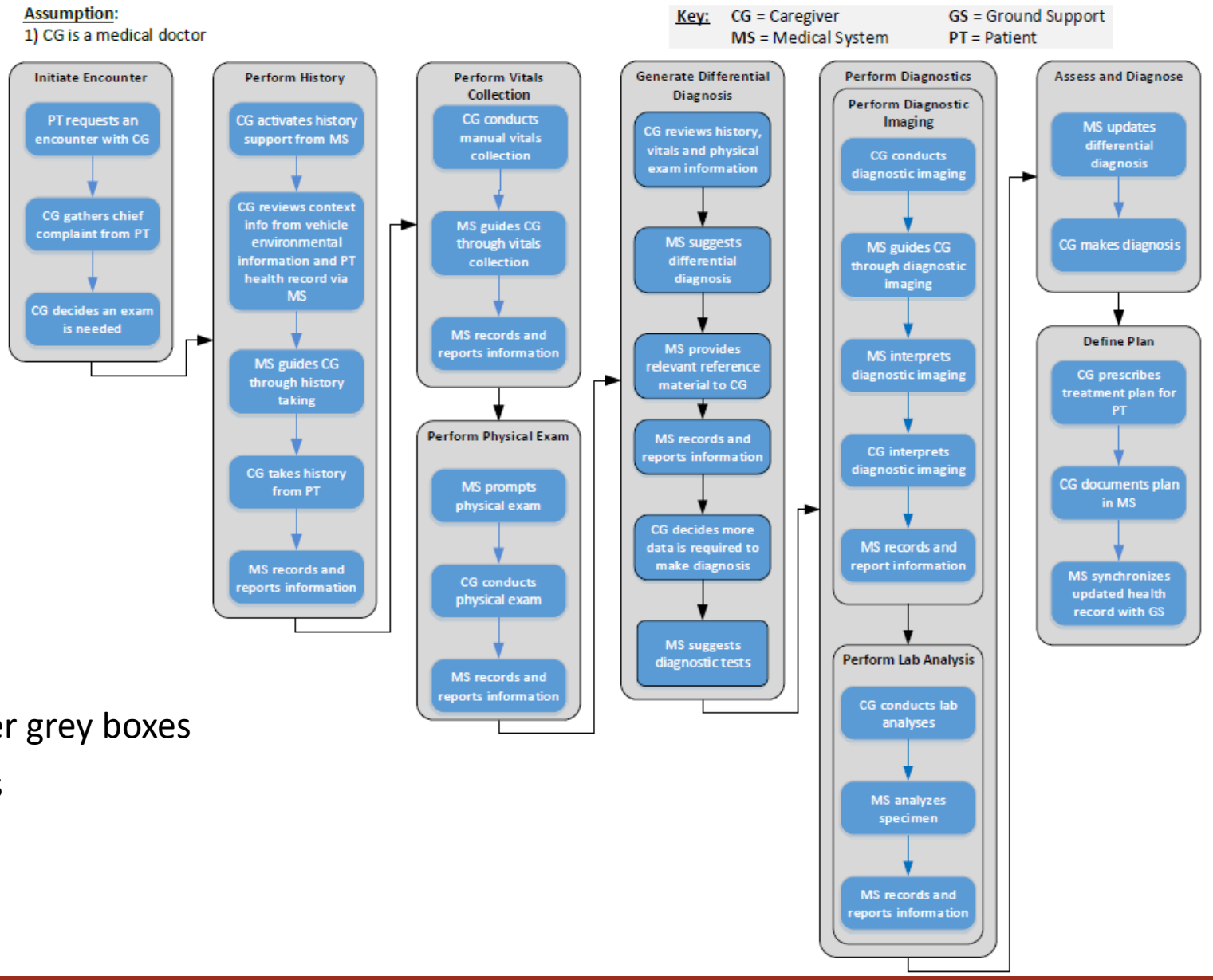
ConOps enables trace to system functional needs -> system requirements -> allocations -> subsystem requirements

Questions?

Backup

Activity Diagram

Scenario Type: Unplanned, Directed Care, Autonomous from Ground



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Acronyms

- Semi- = Semi-autonomous
- Fam. Conf. = Family Conference
- Pysch. Conf. = Psychological Conference
- CME = Continued Medical Education
- UTI = Urinary Tract Infection
- Exercise hw malf. = Exercise hardware malfunction
- JITT = Just-in-Time Training
- DCS = Decompression Sickness